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Design and Development of Flat Belt Dimpled Pulley

Tushar J. Godage[1*], Bhagwat Randhavan[2]
[1]*Student, Department of ME Design, Sahyadri Valley College of Engineering and Technology, Pune, India*
[2]*Professor, Department of ME Design, Sahyadri Valley College of Engineering and Technology, Pune, India*

***Abstract*: Belt transmissions are often used in industry machinery to transmit power. Other fields of the application that concerns Front End Accessory of Automotive engines drive, it recently asks for the performances that allow development of new technology innovations as starter-alternator integration in transmission. Belt slips on the pulley causes the transmission error. This can be controlled to some extent using appropriate initial tension. The flat belt pulley surface is plain. In the present study, the effect of positive geometry square and round shape dimpled surface instead of plain is investigated. The remaining parameters except the contact surface of belt and pulley are same. The experimental set up developed is used to determine the belt slip and slip torque for varying load and speed conditions. Two different dimple geometries are considered for this investigation. The paper elaborates how we can improve performance by application of aluminum material liners on the flat pulley. This one is relatively newer method. For Geometrical profile design of square & round shape positive geometry flat belt pulley we use 2-d cad, for 3-d modeling we use Unigraphix N-x.**

***Keywords*: Belt transmissions, contact surface, flat belt pulley, transmission error, Slip, Aluminium liner, Square, Round indent geometry.**

1. Introduction

1) Belt Drives Applications

Flexible Machine Elements Belt drives are also called as the flexible machine elements. Belt drive are usable for large number of industrial applications for e.g. Transportation of the coal, mineral ores etc. in the conveying systems etc. Over long distance, Used for the power transmission. This is majorly used for the running various industrial appliances using prime movers like electric motors and I.C. Engine etc. and replacement of rigid type power transmission systems. Gear drives can be replaced by a belt transmission system flexible machine element as it has got an inherent advantage that, a good amount of shock and vibration can be absorbed by it. A belt is loop of the flexible material which is used to link more rotating shafts mechanically to each other, most often parallel. Belts can be used as the source of motion, to transmit power efficiently and to track the relative movements. As belt transmits power by the friction contact between the belt and driving and driven sheave, and Belt drives for power transmission are classed as frictional drives. Power transmission belts are available in various types such as: flat belts, V-belts, multi-ribbed belts and synchronous belts.

2) Belt selection consideration

Condition in which environment belt will be operating e.g. exposure to oil and grease, range of operating temperatures, abrasive dust and various chemical condition, sunlight, and many other weather condition. Other considerations which included are as the drives Type required, Driver or Driven Revolutions Per Minute (RPM), Horsepower required, diameters of the pulley and center distance, Take-up allowance also take-up design, and operational Space limitations, Pulsating or shock load conditions. Due to their versatility and high efficiency synthetic flat belts are currently used in all the areas of power transmission technology, excellent properties and outstandingly reliable.

2. Literature Review

General: Multiple literatures gathered to study & investigated to design Flat belt dimpled pulley. Based on information from these literature various parameters are selected and designed. “Power Transmission through Timing Belt in Two Wheeler Motors” – by Gurumurthy Veerapathiran and Prabu Dhanapal1, Ranjithkumar Koumaravel, Padmanaban Narayanamoorthy and Ravish Vignesh. In this paper authors studied the effect by noise and friction on performance of chain drive system of bikes. Experiments show that in the chain drive, chain transmission system causes poor performances, due to its noise and chain gets loosen because of the aging and sprockets wear because of friction in chain. The system proposed here consisting of the drive and driven pulley with timing belts transmission. When compared to conventional method this method give improved tension in pulleys and belt by additional arrangement also called as belt tensioner. This gives good system performance and reduction in noise, vibration and gives increased transmission speed.

“Modelling, System Identification and Control of a Belt Drive System” By Shenjin Zhu (McMaster University, Canada).This paper is useful in development of mathematical model of an experimental system of belt drive by using physical

*Corresponding author: godagetushar222@gmail.com

modelling and system identification. This model is useful for the designing of advanced robust discrete-time controller. This paper provide vast literature review, that covers modelling and control of the belt drive system as well sliding mode control (SMC) theory. Physical modelling is carried out for experimental system followed by system identification. Both the identified as well as physical models are used for analyse and investigate characteristics of system. Various control approaches like discrete-time proportional integral derivative (DPID) also discrete-time sliding mode control (DSMC) are designed as well as implemented. The results are compared, conclusions are drawn from two control approaches.

"Coupled belt-pulley mechanics in serpentine belt drives" By Lingyuan Kong, B.S., M.S. This paper studies belt vibration and slip which are primary concerns in the design of the serpentine belts drives. Belt-pulley coupling is essential for analysis. This work investigates the issues to advance understanding of the belt pulley mechanics. This model can be explain transverse span vibrations caused by the crankshaft pulley fluctuations at low engine idle speeds where other coupling mechanism do not. For steady state analysis, novel transformation of governing equations to the standard ODE form for the general-purpose BVP solvers caused numerically to exact steady solution. The approach is the straightforward, suited for different boundary conditions, and has physical accessible.

3. Problem Statement

The flat belt drives are normally used for high speed power transmission between shafts. Even though the required characteristic flat belt is to transmit high speed power, slip is the major issue. Thus it is important to address this by application of suitable remedial methods.

1) Power Loss in belt transmission system

Synchronous belt drive generates resonance on the belt span between two pulleys. When the transverse natural frequency matches with meshing frequency of the belt tooth and tooth that of pulley, the resonance occurs. The resonance effects on accuracy of transmission [1]. Belt tensions are needed to be too small as possible to increase belt fatigue strength and prolong bearing life and power loss from belt slip is unacceptable. If the belt speed is very much high and considers the flexibility of belt then inertial forces is taken into consideration which is added in equilibrium equation includes tangential and radial inertial forces [2]. For keeping flat belt centered a crown pulley is used but it tends to cause belt tension concentration so it reduces the belt life. Misalignment between two flat pulleys is called as "skew" [3]. The pulley grooves generates two dimensional radial and tangential forces whose undetermined directions are dependent on relative speed between belt and pulley along the arc of contact. A new computational technique developed to find steady mechanics of v- belt drive. This system analyses the speed, torque loss and maximum tension ratio [4].

Lateral belt motion in belt drive is investigated which includes belt over arbitrary shape with angular misalignment. In this cylindrical and conical pulley is considered, which identifies mean normal stress in the belt, its stiffness and width of belt [5]. Serpentine belt drives that used in front end accessory drive of automobile engine. Belt transmission is always used for higher capacity. In this case two types of tensioners are selected to maintain minimum tension that insures power transmission and minimum slip. Two tensioners are dry friction tensioner and hydraulic tensioner [6]. The surface with groove pattern and mesh pattern have higher co-efficient of friction than the flat surfaces, but the surfaces with dimpled pattern have lower coefficient of friction than the flat surface. It has been reported that dimples on the surface acted as fluid reservoir during sliding and this reduced the maximum contact pressure.

2) Various Techniques Used to reduce losses

Various techniques for texturing surface have been developed such as milling by using machine tools, etching process, shot blasting and laser beam processes. Applying texturing on the surfaces is one way to improve the tribological properties [7]. Adhesive friction theory considers the friction force to be the product of real area of contact between sliding surfaces and shear stress at the contact. These values have been separately measured by running different belts over transparent pulleys and observing the contact [8]. Dynamic coefficient of the friction at any point on contact arc is determined from slip and tension measurement on operating belt and solution is found by the utilization of experimental slip measurement.

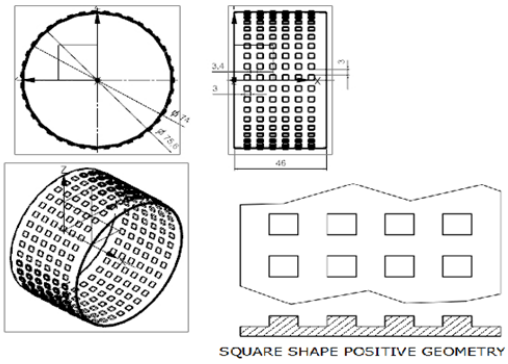

Fig. 1. Positive Geometry Square Shape Projection on Dimpled Pulley

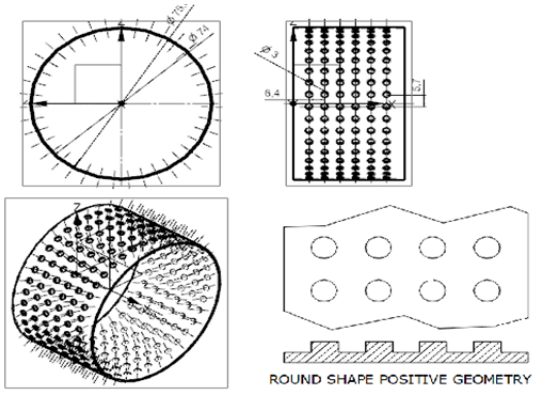

Fig. 2. Positive Geometry Round Shape Projection on Dimpled Pulley

3) Objective of project

1. Design, development, analysis of square shape positive geometry flat belt pulley liner. Geometrical

profile design using 2-d cad, 3-d modeling using Unigraphix N-x, analysis using Ansys work bench.

2. Design development and analysis of round shape positive geometry flat belt pulley liner. Geometrical profile design using 2-d cad, 3-d modeling using Unigraphix N-x, analysis using Ansys work bench.

4. Design and Analysis

1) Design and Analysis of Flat belt pulley

1. 3D Model & Specifications: 3-D Modeling software Unigraphix N-x was used for generating model of flat belt pulley. Refer below indicated figures for flat belt pulley details.

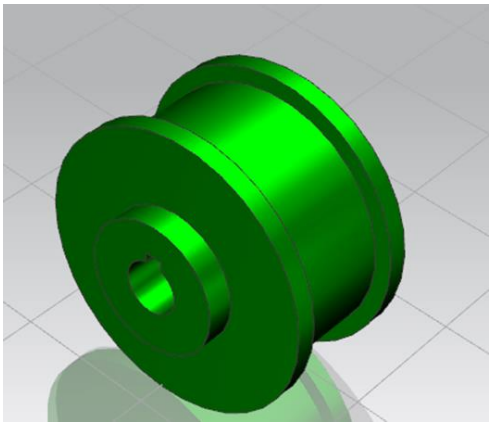

Fig. 3. 3-D Modeling of flat belt pulley in Unigraphix N-x

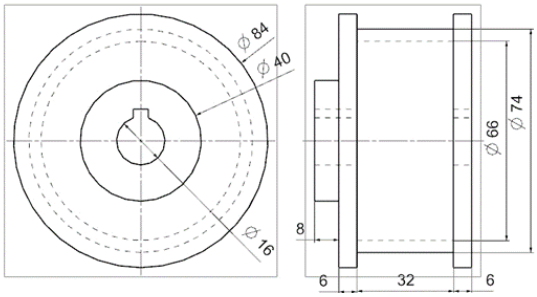

Fig. 4. 2-D Details of flat belt pulley

2) Specification-

Motor:
50 watt, 0 to 6000 rpm variable speed, 230 volt AC
Gear details of drive from motor to pulley:
Pinion on motor = 10 teeth 2 module
Gear on driver shaft = 40 teeth = 2 module
Driver shaft speed = 6000 / 5 = 1200 rpm
Torque @ driver shaft = 0.398 N-m = 0.4 N-m
Considering Factor of safety = 2
T design = 0 x 0.4 = 0.8 N-m

3) Material

Designation	Ultimate Tensile strength N/mm^2	Yield strength N/mm^2
Aluminium	360	240

$\Rightarrow$ fs max allowable = 90 N/mm^2 (considering factor of safety =4)

Check for torsional shear failure:-

$$T = \frac{\Pi \times fs_{act} \times}{16} \left[\frac{Do^4 - Di^4}{Do}\right]$$

$$800 = \frac{\Pi \times fs_{act} \times}{16} \left[\frac{74^4 - 66^4}{74}\right]$$

$\Rightarrow fs_{act} = 0.086017$ N/mm^2

As; $fs_{act} < fs_{all}$

$\Rightarrow$ Pulley is safe under torsional load.

4) Meshing

Meshing is done on flat belt pulley for easy solving & accurate results in ANSYS 16.0. In 3D modelling only 2 types of meshes are possible namely hexa & tetra. In tetra meshing we have free meshing whereas for hexa meshing either of free or mapped meshing is available.

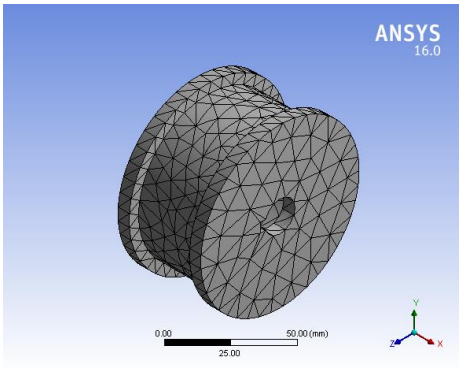

Fig. 5. Meshing of Flat belt pulley for structural analysis

5) Load and boundary conditions

Material assets play a main part in the result of the FE analysis. The material assets are single of the chief input to do FEA analysis & optimization. Applying boundary situation and exact loading is very essential to obtain accurate results of analysis.

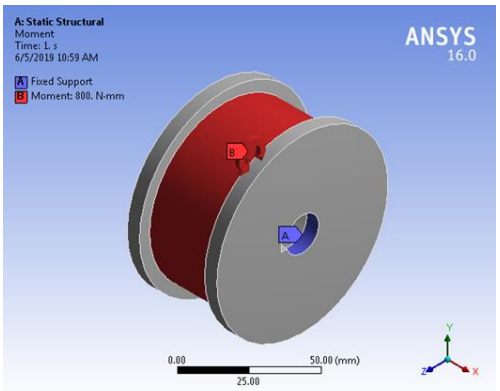

Fig. 6. Boundary condition applied on Flat belt pulley

6) Analysis of Flat belt pulley

We select aluminum as material for analysis next is the properties of substantial for structural analysis,

Material: Aluminum
Poisson's ratio: 0.32
Density: 2700 kg/m^3

Examination of Flat belt pulley is completed by using properties of material given above. While analysis of Von-Mises Stresses, Deformation, Max principle stress are to be find out.

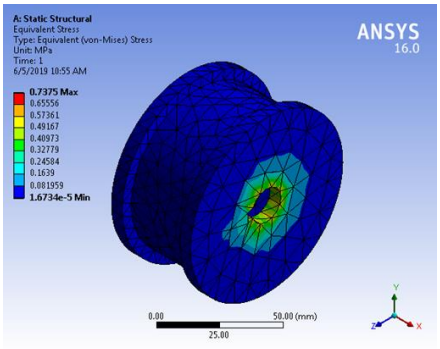

Fig. 7. Von Misses Stress distribution

As the maximum stress induced is 0.7375 Mpa which is less than the allowable stress hence the pulley is safe.

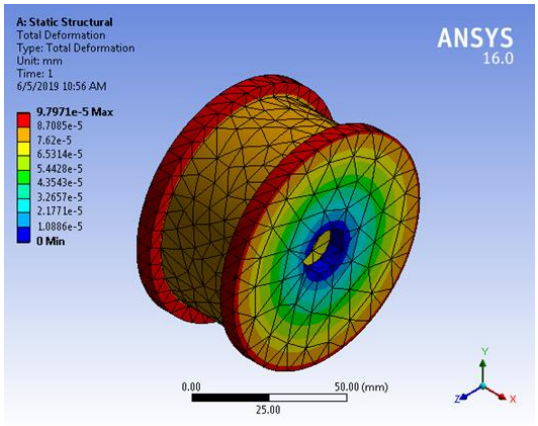

Fig. 8. Deformation of flat belt pulley

7) Design of Round indent geometry liner

3D Model & Specifications: 3-D Modeling software Unigraphix N-x was used for generating model of round indent geometry liner. Refer below indicated figures for flat belt pulley details.

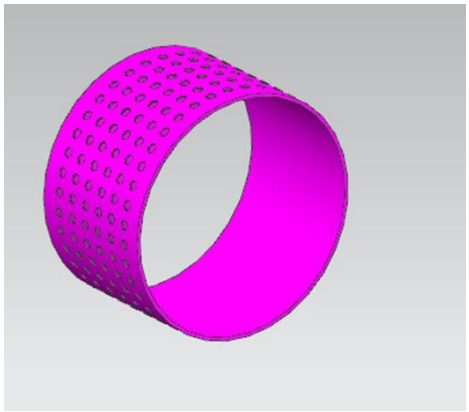

Fig. 9. 3-D Modeling round indent geometry liner in Unigraphix N-x

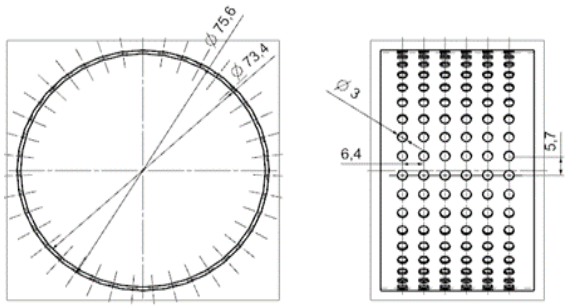

Fig. 10. 2-D Details of round indent geometry liner

8) Material selection

Designation	Ultimate Tensile strength N/mm^2	Yield strength N/mm^2
Aluminium	360	240

$\Rightarrow$ fs max allowable = 90 N/mm^2 (considering factor of safety =4)

Check for torsional shear failure:-

$$T = \frac{\Pi \times fs_{act} \times \left(\frac{Do^4 - Di^4}{Do}\right)}{16}$$

$$800 = \frac{\Pi \times fs_{act} \times \left(\frac{75.6^4 - 73.4^4}{75.6}\right)}{16}$$

$\Rightarrow fs_{act} = 0.26588 N/mm^2$

As; $fs_{act} < fs_{all}$

$\Rightarrow$ Round indent geometry liner is safe under torsional load.

9) Meshing

Meshing is done on round indent liner for easy solving & accurate results in ANSYS 16.0. In 3D modelling only 2 types of meshes are possible namely hexa & tetra. In tetra meshing we have free meshing whereas for hexa meshing either of free or mapped meshing is available.

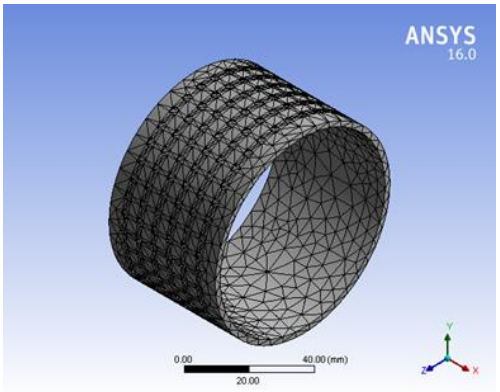

Fig. 11. Meshing of round indent liner structural analysis

10) Load and boundary conditions:

Material assets play a main part in the result of the FE analysis. The material assets are single of the chief input to do FEA analysis & optimization. Applying boundary situation and exact loading is very essential to obtain accurate results of analysis.

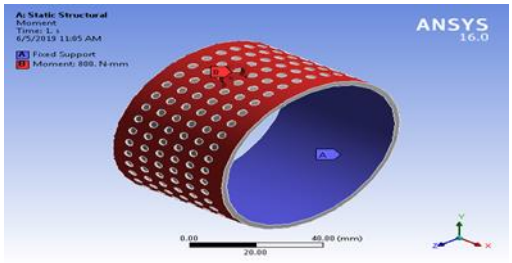

Fig. 12. Boundary condition applied on round indent liner

11) Analysis of Round indent liner

We select aluminum as material for analysis next is the properties of substantial for structural analysis,

Material: Aluminum

Poisson's ratio: 0.32

Density: 2700 kg/m3

Examination of round indent liner is completed by using properties of material given above. While analysis of Von-Mises Stresses, Deformation, Max principle stress are to be find out.

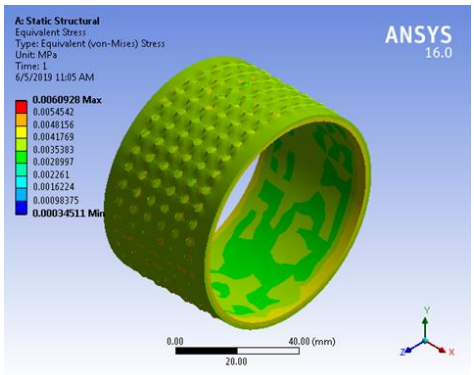

Fig. 13. Von Misses Stress distribution

As the maximum stress induced is 0.06 Mpa which is less than the allowable stress hence the pulley is safe

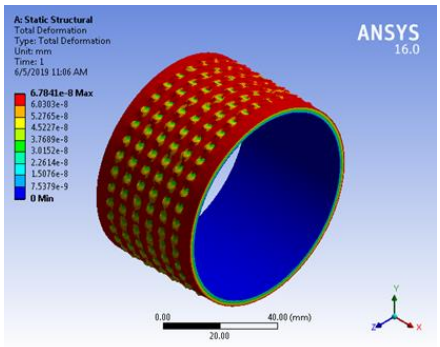

Fig. 14. Deformation of round indent liner

12) Design and Analysis of Square Geometry liner

3D Model & Specifications: 3-D Modeling software Unigraphix N-x was used for generating model of square geometry liner. Refer below indicated figures for square geometry liner.

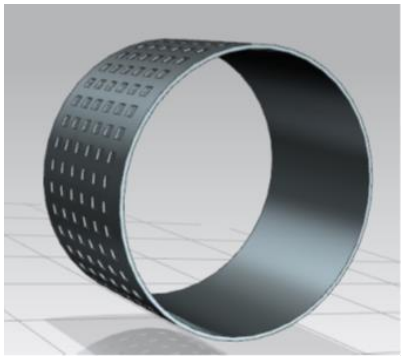

Fig. 15. 3-D Modeling of square geometry liner in Unigraphix N-x

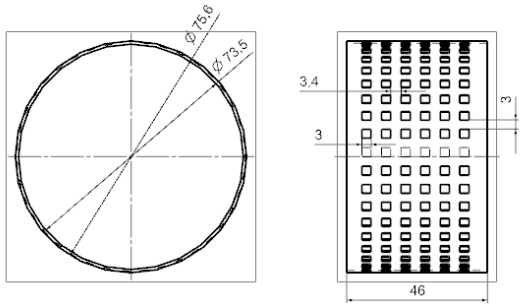

Fig. 16. 2-D Details of square geometry liner

13) Meshing

Meshing is done on square indent liner for easy solving & accurate results in ANSYS 16.0. In 3D modelling only 2 types of meshes are possible namely hexa & tetra. In tetra meshing we have free meshing whereas for hexa meshing either of free or mapped meshing is available.

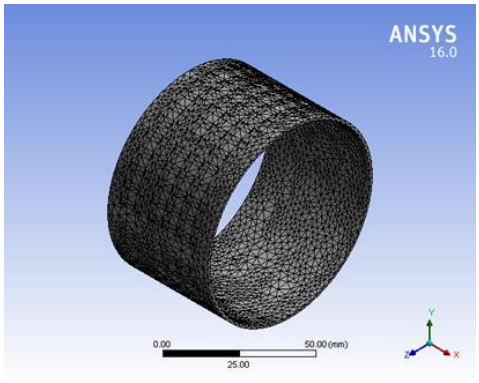

Fig. 17. Meshing of round indent liner for structural analysis

14) Load and boundary conditions:

Material assets play a main part in the result of the FE analysis. The material assets are single of the chief input to do FEA analysis & optimization. Applying boundary situation and exact loading is very essential to obtain accurate results of analysis.

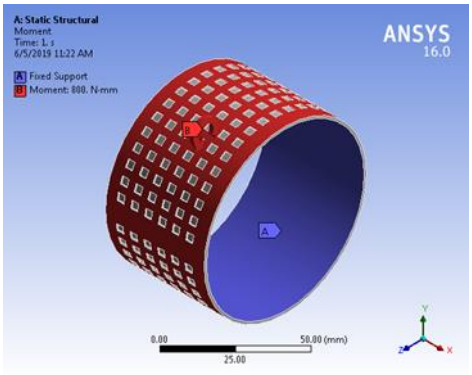

Fig. 18. Boundary condition applied on square indent liner

15) Analysis of round indent liner

We select aluminum as material for analysis next is the properties of substantial for structural analysis,

Material: Aluminum

Poisson's ratio: 0.32

Density: 2700 kg/m3

Examination of round indent liner is completed by using properties of material given above. While analysis of Von-Mises Stresses, Deformation, Max principle stress are to be find out.

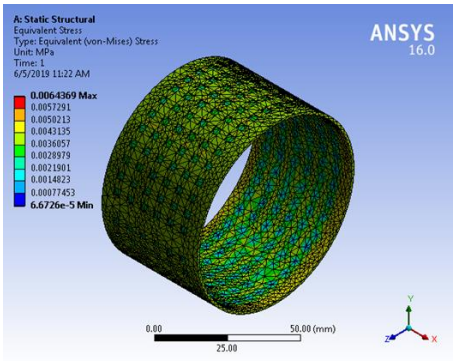

Fig. 19. Von Misses Stress distribution

As the maximum stress induced is 0.06 Mpa which is less than the allowable stress hence the pulley is safe.

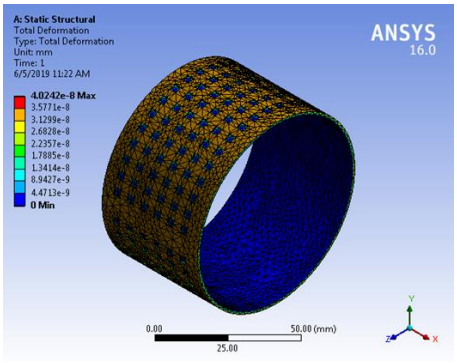

Fig. 20. Round indent liner Deformation

5. Experimental Setup

The selected mechanism and machine along with the damper will be designed with the help of following machines

- Centre lathe
- Milling machine
- DRO – Jig Boring machine
- Electrical Arc Welding

1) Experimental setup

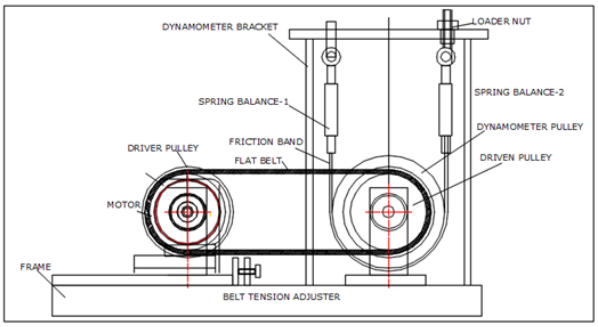

Fig. 21. Experimental Setup

Experimental Set up which is developed for measuring slip on driven pulley. A brake is applied on driven shaft with the help of load variation by nut and screw arrangement. Load is measured by spring balance attached to a brake drum. Set up that includes driving pulley, driven pulley, flat belt (of nylon) middle polyamide surface, Brake drum with friction band Motor specifications single phase ac variable speed with spur gear drive.

6. Conclusion

Flat belt pulley surface is plain which causes more slip and affects efficiency. To investigate effect of positive geometry square and round shape dimpled surface instead of plain set up is designed. Comparative analysis of plain, square dimpled and round dimpled pulleys, also test and trial to determine slip and characteristic of percentage slip Vs. load and percentage slip Vs. torque will give us information weather objectives of the project achieved or not.

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